

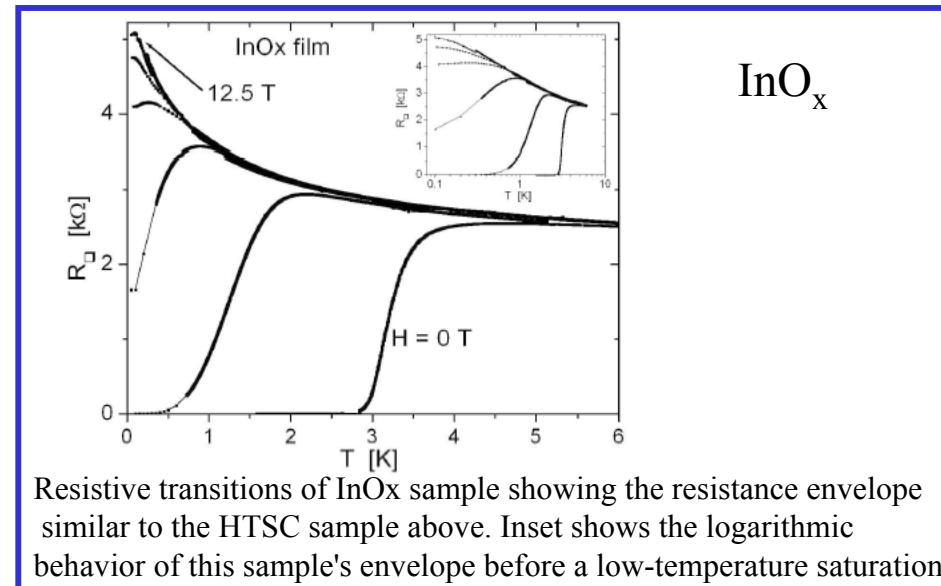
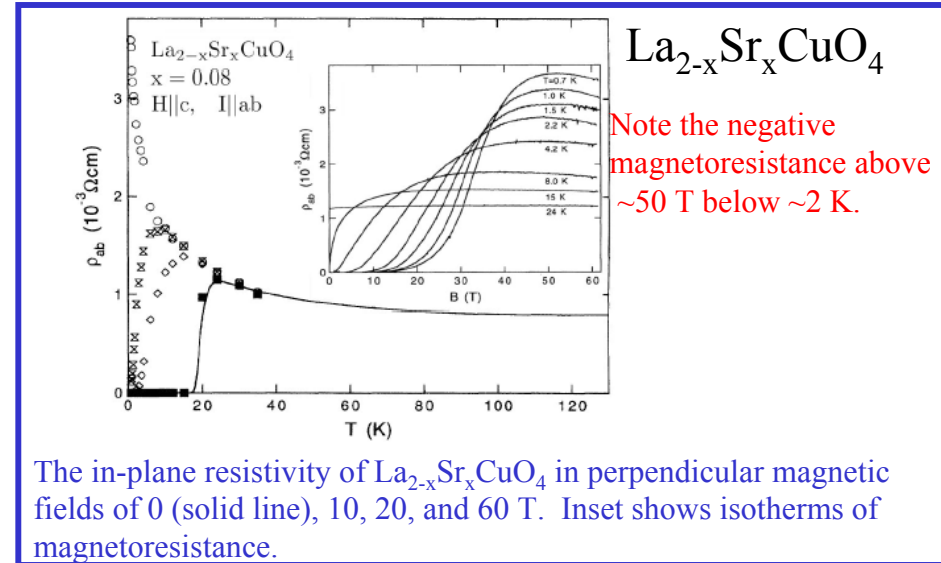
Superconductors, Insulators, Metals and Quantum Phase Transitions in Two-Dimensional Films

A. Kapitulnik & M.R. Beasley, Stanford University DMR-0119027

Homogeneous InO_x films in the superconducting state show great similarity in their field and temperature dependences to high-temperature superconductors (HTSC). However, the same features observed in $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ or $\text{Bi}_2\text{Sr}_{2-x}\text{La}_x\text{CuO}_{6+\delta}$ at fields of order 60 T, are observed in InO_x films at ~ 10 T, allowing us to observe the full development of a Bose-insulating state, and its subsequent weakening at higher fields.

Based on the results obtained on InO_x we assert that the insulating behavior observed for HTSC upon the application of a magnetic field evidences a tendency towards a Bose-insulating phase[#].

[#] M.A. Steiner, G. Boebinger and A. Kapitulnik, 2004.



Understanding the nature of the normal state of high-temperature superconductors (HTSC) is an important part of understanding the cause for high- T_c in these materials. In particular, understanding the underlying normal state in the temperature range where the materials are superconducting has been attempted in many experiments. For low-temperature BCS superconductors (LTSC) this is easily accomplished by the application of a magnetic field larger than the upper critical field, H_{c2} thereby breaking all pairs and usually revealing an underlying Fermi liquid state. However, attempting such a procedure for HTSC has proven difficult due to the intense magnetic fields required and the fragility of the vortex state. While dissipation due to the melting or depinning of the vortices is easily achieved, recent experiments indicate that pairing and vortices persist to very high magnetic fields.

In this work we show that homogeneous InOx films in the superconducting state show great similarity in their field and temperature dependences to $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ and $\text{Bi}_2\text{Sr}_{2-x}\text{La}_x\text{CuO}_{6+\delta}$. Our results suggest that indeed, the logarithmically diverging “insulating state” found in the underdoped HTSC is primarily a collective Bose-insulator state emerging from a nearby SIT. Upon further increase in the magnetic field above a field of order $H_{c2}(0)$, a dramatic increase in pair-breaking occurs and the insulating phase is strongly suppressed. However, we find in our InOx films that the magnetic field suppresses the pair-amplitude very slowly out to unexpectedly high fields, and the system retains a vestige of pairing at fields as high as three times the expected upper critical field.

Superconductors, Insulators, Metals and Quantum Phase Transitions in Two-Dimensional Films

A. Kapiulnik & M.R. Beasley, Stanford University **DMR-0119027**

Education:

Two graduate students contributed to this work. Nadya Mason started this work in 2001. She received her Ph.D. in 2002. Myles Steiner who performed all the recent experiments is a current graduate student. The present work prompted new experiments that are currently performed by Steiner.

Based on this NSF grant, new insight have been gained on two-dimensional superconductors that apply to other quasi-two dimensional systems such as high-temperature superconductors. These results motivated the PI to design a new graduate course that will be taught by him for the first time in AY-2004/05.

Societal Impact:

Progress in our understanding complex electronic systems depends on our ability to isolate different effects and study them separately. The approach of designing model systems is particularly useful.

Here we use InO_x as a model system for a single layer HTSC. The short coherence length and low superfluid density of this system makes it particularly suitable for these studies.